

Analysis of the logarithmic slope of F_2 from the Regge gluon density behavior at small x

G.R.Boroun ^{1*}

¹Physics Department, Razi University, Kermanshah 67149, Iran

Abstract

We study of the accuracy of the Regge behavior of the gluon distribution function for obtain an approximation relation, which is frequently used to extract the logarithmic slopes of the structure function from the gluon distribution at small x . We show that the Regge behavior analysis results are comparable with HERA data and also are better than other methods that expand of the gluon density at distinct points of expansion. Also we show that for $Q^2 = 22.4 GeV^2$, the x dependence of the data is well described by gluon shadowing corrections to GLR-MQ equation. The resulting analytic expression allow us to predict the logarithmic derivative $\frac{\partial F_2(x, Q^2)}{\partial \ln Q^2}$ and to compare the results with H1 data and a QCD analysis fit with MRST parametrization input.

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*Email: grboroun@gmail.com

Previously several methods of relation between the F_2 scaling violations and the gluon density at low x has been suggested [1-3]. All methods are based on an approximate relation, as using the fact that quark densities can be neglected and that the nonsinglet contribution F_2^{Ns} can be ignored safely. To investigate, we have used the DGLAP evolution equations [4] for four flavours:

$$\frac{dF_2}{d\ln Q^2} = \frac{5\alpha_s}{9\pi} \int_x^1 dz G\left(\frac{x}{z}, Q^2\right) P_{qg}(z), \quad (1)$$

where $P_{qg}(z) = (1-z)^2 + z^2$.

In LO (leading order), Pretz's [1] shows an approximation relation between the gluon density at the point $2x$ and the logarithmic slopes F_2 at the point x , as the final relation was found:

$$\frac{dF_2}{d\ln Q^2} = \frac{5\alpha_s}{9\pi} \frac{2}{3} G(2x, Q^2). \quad (2)$$

Bora's [2] shows similar relation based on expansion of the gluon distribution around $z = 0$, as was found:

$$\frac{dF_2}{d\ln Q^2} = \frac{5\alpha_s}{9\pi} \frac{3}{4} G\left(\frac{4}{3}x, Q^2\right). \quad (3)$$

Also Gay Ducati and Concalves [3] show this expansion at an arbitrary point of expansion. As in the limit $x \rightarrow 0$, the equation becomes:

$$\frac{dF_2}{d\ln Q^2} = \frac{5\alpha_s}{9\pi} \frac{2}{3} G\left(\frac{x}{1-a}\left(\frac{3}{2} - a\right), Q^2\right). \quad (4)$$

They could conclude that the better choice is at $a = 0.75$, as:

$$\frac{dF_2}{d\ln Q^2} = \frac{5\alpha_s}{9\pi} \frac{2}{3} G(3x, Q^2). \quad (5)$$

All relations (2,3 and 5) estimate the logarithmic slopes F_2 with respect to the gluon distribution function at the points $2x$, $\frac{4}{3}x$ and $3x$. In the present letter, we extend the method using

the Regge technique. We first introduce the Regge behavior of the gluon distribution, as can be expressed by:

$$G(x, t) = A_g x^{-\lambda_g(t)}, \quad (6)$$

where A_g is a constant and λ_g is the intercept ($t = \ln \frac{Q^2}{\Lambda^2}$). Using this behavior and after integrating and some rearranging, we find an approximation relation between the $dF_2(x, Q^2)/d\ln Q^2$ and $G(x, Q^2)$ at the same point x , as we have:

$$\frac{dF_2}{d\ln Q^2} = \frac{5\alpha_s}{9\pi} T(\lambda_g) G(x, Q^2). \quad (7)$$

where $T(\lambda_g) = \int_x^1 dz z^{\lambda_g} (1 - 2z + 2z^2)$.

Relation (7) [5] helps to estimate the logarithmic slopes F_2 in the leading logarithmic approximation (LLA). We note also that if we wish to evolve shadowing corrections to the gluon density, we can simply show these recombinations with respect to Gribov, Levin, Ryskin, Mueller and Qiu (GLRMQ)[6,7] equations. These nonlinear terms reduce the growth of the gluon distribution in this kinematic region where α_s is still small but the density of partons becomes so large. According to the fusion of two gluon corrections, the evolution of the shadowing structure function with respect to $\ln Q^2$ corresponds with the modified DGLAP evolution equation. So we have

$$\frac{\partial F_2^s(x, Q^2)}{\partial \ln Q^2} = \frac{5\alpha_s}{9\pi} T(\lambda_g) G^s - \frac{5}{18} \frac{27\alpha_s^2}{160 R^2 Q^2} [G^s]^2, \quad (8)$$

where R is the size of the target which the gluons populate. The value of R depends on how the gluon ladders couple to the proton, or on how the gluons are distributed within the proton. R will be of the order of the proton radius ($R \simeq 5 \text{ GeV}^{-1}$) if the gluons are spread throughout the entire nucleon, or much smaller ($R \simeq 2 \text{ GeV}^{-1}$) if gluons are concentrated in hot-spot [9] within the proton. We show a plot of $\frac{\partial F_2(x, Q^2)}{\partial \ln Q^2}$ in Fig.1 for a set of values of x at Q^2 constant at hot spot point $R = 2 \text{ GeV}^{-1}$, compared to the values measured by the H1 collaboration [10] and a fit to ZEUS data inspired by the Froissart bound[11] based on MRST

input parametrization [12]. In Fig.1 we show our results of $\frac{dF_2}{d\ln Q^2}$ obtained from the Regge behavior of the gluon density that compared with other models based on the expansion of the gluon density. For these results, the input gluon used from MRST parameterizations. It is clear that our results based on this behavior are lowest than other models. Also, from this figure one can see that GLR-MQ equation tamed behavior with respect to gluon saturation as x decreases. This shadowing correction suppress the rate of growth in comparison with the DGLAP approach. To conclude, At high density the recombination of gluons becomes dominant, and must be included in the calculations. When the shadowing term is combined with DGLAP evolution in the double leading log approximation (DLA), then we obtain the GLR-MQ equation for the integrated gluon. So that, we have solved the DGLAP equation, with the nonlinear shadowing term included, in order to determine the very small x behavior of the gluon distribution $G(x, Q^2)$ of the proton. In this way we were able to study the interplay of the singular behavior, generated by the linear term of the equation, with the taming of this behavior by the nonlinear shadowing term. With decreasing x , we find that an $\sim x^{-\lambda_g}$ behavior of the gluon function emerges from the GLR-MQ equation. Based on our present calculations we conclude that the behavior of $\frac{\partial F_2(x, Q^2)}{\partial \ln Q^2}$ as measured by HERA, tamed based on gluon saturation at low x . Our results show that the data can be described in PQCD taking into account shadowing corrections.

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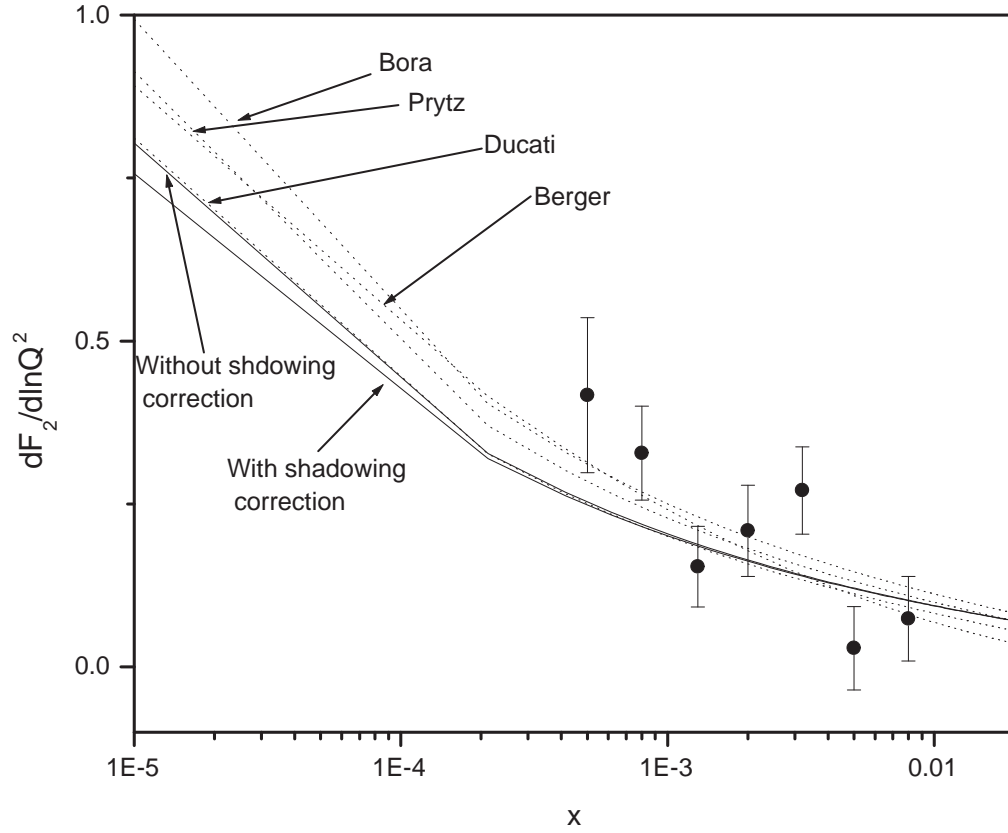


Figure 1:

Figure captions

Fig 1: A plot of the derivative of the structure function with respect to $\ln Q^2$ vs. x for $Q^2 = 22.4 \text{ GeV}^2$ with MRST parametrization [12], compared to data from H1 Collab.[10] (circles) with total error, and also a QCD fit [11] and other models [1-3] (Dot curves). Solid curves are our results with and without shadowing correction with respect to the Regge behavior of the gluon density.